SEISMIC HAZARD ZONE REPORT 099

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SEISMIC HAZARD ZONE REPORT FOR THE LITTLEROCK 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

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California Geological Survey

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This report summarizes the methods and sources of information used to prepare the Seismic Hazard Zone Map for the Littlerock 7.5-Minute Quadrangle, Los Angeles County, California. The map displays the boundaries of zones of required investigation for liquefaction and earthquake-induced landslides over an area of approximately 62 square miles at a scale of 1 inch = 2,000 feet.

The Littlerock 7.5-Minute Quadrangle lies in the Antelope Valley in northeastern Los Angeles County. The center of the area is 10 miles east of Palmdale and 40 miles northeast of the Los Angeles Civic Center. High desert scrubland and grassland of low local relief characterize most of the area. The southern slopes of Alpine Butte are in the northeastern corner. Irregular, hilly terrain along the San Andreas Fault Zone occurs in the extreme southwestern corner. Broad active channels and the adjacent floodplain of Little Rock Wash extend along the western part of the quadrangle. A segment of Big Rock Wash is in the northeastern corner. The eastern limits of the City of Palmdale cross into the western part of the quadrangle and extend eastward to 120th Street East, north of Avenue Q. Most of the desert community of Littlerock and much of the smaller community of Pearblossom are within the quadrangle. Except for Palmdale all other land in the quadrangle is unincorporated Los Angeles County land. Many gravel pits are adjacent to Little Rock Wash. Land uses include residential developments, small ranches, mining, and recreation.

The map is prepared by employing geographic information system (GIS) technology, which allows the manipulation of three-dimensional data. Information considered includes topography, surface and subsurface geology, borehole data, historical ground-water levels, existing landslide features, slope gradient, rock-strength measurements, geologic structure, and probabilistic earthquake shaking estimates. The shaking inputs are based upon probabilistic seismic hazard maps that depict peak ground acceleration, mode magnitude, and mode distance with a 10 percent probability of exceedance in 50 years.

The liquefaction zone covers about 13 square miles in the east-central part of the Littlerock Quadrangle surrounding the Big Rock Creek floodplain. A swath of land adjacent to the Little Rock Creek floodplain on the western part of the quadrangle is also within the liquefaction zone. Very small patches on Alpine Butte and within the hills along the San Andreas Fault Zone in the southwestern corner are within the earthquake-induced landslide zone that covers less than one percent of the quadrangle.

How to view or obtain the map

Seismic Hazard Zone Maps, Seismic Hazard Zone Reports and additional information on seismic hazard zone mapping in California are available on the California Geological Survey's Internet page: http://www.consrv.ca.gov/CGS/index.htm

Paper copies of Official Seismic Hazard Zone Maps, released by CGS, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available for purchase from:

BPS Reprographic Services
149 Second Street
San Francisco, California 94105
(415) 512-6550

Seismic Hazard Zone Reports (SHZR) summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These reports are available for reference at CGS offices in Sacramento, San Francisco, and Los Angeles. **NOTE: The reports are not available through BPS Reprographic Services.**

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. They must withhold development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans. The Act also requires sellers (and their agents) of real property within a mapped hazard zone to disclose at the time of sale that the property lies within such a zone. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board (SMGB) (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp

The Act also directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. They also directed CGS to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that 1) the process for zoning liquefaction hazards remain unchanged and 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Zone Report summarizes the development of the hazard zone map. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historical ground-water information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10 percent probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the Littlerock 7.5-Minute Quadrangle.

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the Littlerock 7.5-Minute Quadrangle, Los Angeles County, California

By
Cynthia L. Pridmore

California Department of Conservation
California Geological Survey

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps developed by CGS in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within seismic hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board (SMGB) (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp

Following the release of DMG Special Publication 117 (DOC, 1997), agencies in the Los Angeles metropolitan region sought more definitive guidance in the review of geotechnical investigations addressing liquefaction hazards. The agencies made their request through the Geotechnical Engineering Group of the Los Angeles Section of the American Society of Civil Engineers (ASCE). This group convened an implementation committee under the auspices of the Southern California Earthquake Center (SCEC).

The committee, which consisted of practicing geotechnical engineers and engineering geologists, released an overview of the practice of liquefaction analysis, evaluation, and mitigation techniques (SCEC, 1999). This text is also on the Internet at: http://www.scec.org/

This section of the evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Littlerock 7.5-Minute Quadrangle. Section 2 (addressing earthquake-induced landslides) and Section 3 (addressing potential ground shaking) complete the report, which is one of a series that summarizes production of similar seismic hazard zone maps within the state (Smith, 1996). Additional information on seismic hazards zone mapping in California is on CGS's Internet web page: http://www.consrv.ca.gov/CGS/index.htm

BACKGROUND

Liquefaction-induced ground failure historically has been a major cause of earthquake damage in southern California. During the 1971 San Fernando and 1994 Northridge earthquakes significant damage to roads, utility pipelines, buildings, and other structures in the Los Angeles area was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction-induced damage are underlain by loose, water-saturated, granular sediment within 40 feet of the ground surface. These geological and ground-water conditions exist in parts of southern California, most notably in some densely populated valley regions and alluviated floodplains. In addition, the potential for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region in general, including areas in the Littlerock Quadrangle.

METHODS SUMMARY

Characterization of liquefaction hazard presented in this report requires preparation of maps that delineate areas underlain by potentially liquefiable sediment. The following were collected or generated for this evaluation:

- Existing geologic maps were used to provide an accurate representation of the spatial distribution of Quaternary deposits in the study area. Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill.

- Construction of shallow ground-water maps showing the historically highest known ground-water levels

- Quantitative analysis of geotechnical data to evaluate liquefaction potential of deposits

- Information on potential ground shaking intensity based on CGS probabilistic shaking maps

The data collected for this evaluation were processed into a series of geographic information system (GIS) layers using commercially available software. The liquefaction zone map was derived from a synthesis of these data and according to criteria adopted by the SMGB (DOC, 2000).

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils generally is confined to areas covered by Quaternary (less than about 1.6 million years) sedimentary deposits. Such areas within the Littlerock Quadrangle consist mainly of alluvial fans, valleys, and floodplains. CGS's liquefaction hazard evaluations are based on information on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth, which is gathered from various sources. Although selection of data used in this evaluation was rigorous, the quality of the data used varies. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations, as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth, density, and thickness of liquefiable materials, depth to ground water, rate of drainage, slope gradient, proximity to free faces, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to assess the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction and zoning evaluations in PART II.

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The Littlerock 7.5-Minute Quadrangle covers approximately 62 square miles in the Antelope Valley in northeastern Los Angeles County. The center of the area is approximately 10 miles east of Palmdale and 40 miles northeast of the Los Angeles Civic Center. Typical high desert scrubland and grassland of low local relief characterize most of the area. The southern slopes of Alpine Butte are in the northeastern corner. Irregular, hilly terrain along the San Andreas Fault Zone occurs in the extreme southwestern corner. This portion of the quadrangle includes the highest point, over 3,310 feet, along the southern boundary. The lowest point, below 2,540 feet, is in Little Rock Wash in the northwestern corner. Broad active channels and adjacent floodplains of Little Rock Wash occur along the western part of the quadrangle, and similarly those of Big Rock Wash and Big Rock Creek occur within the northeastern corner.

The eastern limits of the City of Palmdale cross into the western part of the quadrangle and extend eastward to 120th Street East, north of Avenue Q. Several square miles in the northwestern corner of the area lie within the proposed Palmdale International Airport. Most of the desert community of Littlerock and much of the smaller community of Pearblossom are within the quadrangle. Except for Palmdale all other land in the quadrangle is unincorporated Los Angeles County land. Access to the region is primarily via State Highway 138 (Pearblossom Highway), east-west avenues (lettered), and north-south streets (numbered).

Land uses include residential developments, small ranches, mining, and recreation. The wildlife sanctuaries of Big Rock Creek, Alpine Butte, and Jackrabbit Flats occur within the Littlerock Quadrangle. A large aggregate-mining operation with many gravel pits is adjacent to Little Rock Wash. A segment of the California Aqueduct and the Pearblossom Pumping Plant are in the southern part of the area.

GEOLOGY

Bedrock and Surficial Geology

Geologic units that are generally susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. For this evaluation, Quaternary geologic maps of the eastern Antelope Valley (Ponti and Burke, 1980, scale 1:62,500) and along the San Andreas Fault Zone (Barrows and others, 1985) were digitized by the Southern California Areal Mapping Project. The geology for the Littlerock Quadrangle was extracted from these regional maps to form a 1:24,000-scale map. Plate 1.1 shows the generalized Quaternary geology of the Littlerock Quadrangle that was used in combination with other data to evaluate liquefaction potential and develop the Seismic Hazard Zone Map.

Approximately 97 percent of the quadrangle is covered by alluvial deposits of Quaternary age. These Late Pleistocene through Holocene surficial deposits are summarized in Table 1.1 and discussed below. Granitic rocks are exposed in the northeastern portion of the quadrangle in the Alpine Buttes area. Along the southern boundary of the quadrangle, granitic and sedimentary rocks are exposed within the hilly terrain along the San Andreas Fault Zone. These bedrock units are discussed in the earthquake-induced landslide portion (Section 2) of this report.

Map Unit		Environment of Deposition	Age
Ponti and Burke	Barrows and others		
	af	artificial fill	modern
Qsc, Qsvc		modern wash	latest Holocene
Qds		sand dune	latest Holocene
Q7c, Q7vc		alluvial fan	latest Holocene
	Qal	alluvial fan	late Pleistocene to latest Holocene
	Qoa	Fluvial	late Pleistocene and Holocene
Q6m, Q6c		alluvial fan	late Pleistocene and Holocene
Q4-5c		alluvial fan and colluvial apron	late Pleistocene
	Qbl, Qn	Fluvial	Pleistocene
Q1-3c		alluvial fan	Pleistocene

Table 1.1. Map units used in the Littlerock Quadrangle.

The youngest sedimentary units on the map include wash, dune, and alluvial fan deposits. The modern wash materials (Qsc, Qsvc) are associated with Little Rock Wash, Rock Creek, and Big Rock Wash. These repeatedly reworked materials are typically unconsolidated, loose, coarse- to very coarse-grained, and have no soil development (Ponte and Burke, 1980; Ponti, 1980). Scattered throughout the quadrangle are sand dunes and ridges (Qds). They typically consist of well-sorted fine to medium sand with no soil development. The latest Holocene wash and alluvial fan deposits (Q7c, Q7vc, and some areas of Qal) consist of coarse- to very coarse-grained sediments with very weakly developed soils (Ponte and Burke, 1980; Ponti, 1980).

Throughout the central portion of the map area and adjacent to the above described units, Q6m and Q6c consist of unconsolidated, loose, medium- to coarse-grained alluvial fan and older wash materials deposited during late Pleistocene to Holocene (Ponte and Burke, 1980; Ponti, 1980). Soils on these materials are weakly developed. Similar materials occur within the alluvial units mapped as Qoa and Qal (Barrows and others, 1985) in the southwestern portion of the map.

Near the community of Pearblossom the late Pleistocene Q4-5c map unit consists of unconsolidated, uplifted, and slightly dissected alluvial fan deposits. These coarse materials have moderately developed soils, distinct horizons and clay accumulations (Ponte and Burke, 1980; Ponti, 1980).

The oldest Quaternary units in the map area (Qbl, Qn, Q1-3c) consist of weakly consolidated, uplifted, and moderately to severely dissected Pleistocene alluvial fan and fluvial deposits. These map units are all very coarse grained (pebble to boulder-size materials) and occur in the southern portion of the quadrangle near bedrock exposures.

Soils on these materials are moderately to well developed with well-formed horizons and clay accumulations (Ponti and Burke, 1980).

Structural Geology

The Littlerock Quadrangle occupies a portion of the Antelope Valley, a wedge-shaped part of the Mojave Desert bounded on the northwest by the Garlock Fault, and on the south by the San Andreas Fault. Within the southwesternmost corner of the Littlerock Quadrangle are traces of the northwest-trending San Andreas Fault Zone.

ENGINEERING GEOLOGY

Information on subsurface geology and engineering characteristics of Quaternary deposits was obtained from borehole logs collected from geotechnical reports. For this investigation, about 90 logs were collected from the files of Los Angeles County Public Works Department, Earth Systems, California Department of Water Resources, and California Department of Transportation. Lithologic and engineering data from 70 logs were entered into the CGS geotechnical GIS database. The characteristics of the Quaternary map units are generalized in Table 1.2 (see Part II -Liquefaction Susceptibility).

From the borehole logs, the Standard Penetration Tests (SPTs) provide a standardized measure of the penetration resistance of geologic deposits and are commonly used as an index of soil density. This in-field test is formally defined and specified by the American Society for Testing and Materials in test method D1586 (ASTM, 1999). Non-SPT geotechnical sampling "blow counts" are converted to SPT-equivalent values. The actual and converted SPT values are normalized to a common-reference [effective-overburden pressure of one atmosphere (approximately one ton per square foot) and a hammer efficiency of 60 percent using a method described by Seed and Idriss (1982) and Seed and others (1985)].

In addition to the SPTs, the results of other engineering tests (dry density, moisture content, sieve analysis, etc.) are used in the Seed-Idriss Simplified Procedure (Seed and Idriss, 1971) to evaluate liquefaction potential of a site (see Part II - Quantitative Liquefaction Analysis). All engineering characteristics, as well as the results of the liquefaction analysis, are posted onto GIS generated cross sections and aid in the overall three dimensional evaluation of the Quaternary deposits.

GROUND WATER

An essential element in evaluating liquefaction susceptibility is the determination of the depths at which soils are saturated by ground water. Saturated conditions reduce the normal effective stress acting on loose, near-surface sandy deposits, thereby increasing the likelihood of liquefaction (Youd, 1973). For zoning purposes, "near surface deposits" include those sediment layers between 0 and 40 feet deep, the interval being derived from item 4a of the SMGB criteria for delineating seismic hazard zones in California (DOC, 2000; see Criteria for Zoning section of this report). Liquefaction evaluations, therefore, concentrate on areas where investigations indicate that young Quaternary sediments are saturated within 40 feet of the ground surface. Unfortunately, unpredictable and dramatic fluctuations in ground water caused by natural processes and human activities make it impossible to anticipate water levels that might exist at the time of future earthquakes. For that reason, CGS uses historically high ground-water levels for evaluating and zoning liquefaction potential. This approach assumes that even in areas where current levels are deep, ground water could return to historically high levels in the future. This has occurred in basins where heavy pumping has ceased and in areas where large-scale ground-water recharge programs have been employed.

To evaluate the highest known water levels for the Littlerock Quadrangle, the water records from Thompson (1929) and California Department of Water Resources (1966, 2003) were evaluated and compared to published regional water elevation maps for the following years: 1958-1965 (Bloyd, 1967); 1979 (Duell, 1987); and 1996 (Carlson and others, 1998). Additionally, the shallow ground-water map prepared for Los Angeles County (Leighton, 1990, plate 3) was also taken into consideration. Staff also used the following publications to evaluate ground-water conditions in the Littlerock Quadrangle and surrounding areas: Johnson (1911); Durbin (1978); Templin and others (1995); Carlson and Phillips (1998); Galloway and others (1998); and Sneed and Galloway (2000). The resulting historically highest ground-water map prepared for liquefaction hazard evaluation within the Littlerock Quadrangle is shown in Plate 1.2.

The earliest records of high ground water within the Antelope Valley come from the compilation of water well records by Johnson (1911). However, the earliest high ground-water records for the Littlerock Quadrangle and adjacent areas (ranging from the mid 1920's to the present) come from Thompson (1929) and DWR (1966; 2003). The interpretation of the historically highest water level (within 40 feet of the surface) for the northeastern portion of the study area (Plate 1.2) is defined by a northwest-dipping water table projected from the shallowest water level measurements reviewed. Two other areas, one near Littlerock and one near Pearblossom, are similarly defined. The active flood area of Little Rock Wash is included because it receives periodic surface water. Digital orthophoto quarter-quadrangle images for the Littlerock Quadrangle were used to define the limits of modern flooding of Little Rock Wash (see Air Photos in References).

PART II

LIQUEFACTION POTENTIAL

Liquefaction may occur in water-saturated sediment during moderate to great earthquakes. Liquefied sediment loses strength and may fail, causing damage to buildings, bridges, and other structures. Many methods for mapping liquefaction hazard have been proposed. Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of liquefaction susceptibility and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to produce a liquefaction potential map. Liquefaction susceptibility is a function of the capacity of sediment to resist liquefaction. Liquefaction opportunity is a function of the potential seismic ground shaking intensity.

The method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985). Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for their mapping of liquefaction hazards in the Los Angeles region. CGS's method combines geotechnical analyses, geologic and hydrologic mapping, and probabilistic earthquake shaking estimates, but follows criteria adopted by the SMGB (DOC, 2000).

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of a soil to loss of strength when subjected to ground shaking. Physical properties of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance to liquefaction. Some of these properties can be correlated to a sediment's geologic age and environment of deposition. With increasing age, relative density may increase through cementation of the particles or compaction caused by the weight of the overlying sediment. Grain-size characteristics of a soil also influence susceptibility to liquefaction. Sand is more susceptible than silt or gravel, although silt of low plasticity is treated as liquefiable in this investigation. Cohesive soils generally are not considered susceptible to liquefaction. Such soils may be vulnerable to strength loss with remolding and represent a hazard that is not addressed in this investigation. Soil characteristics and processes that result in higher measured penetration resistances generally indicate lower liquefaction susceptibility. Thus, blow count and cone penetrometer values are useful indicators of liquefaction susceptibility.

Saturation is required for liquefaction, and the liquefaction susceptibility of a soil varies with the depth to ground water. Very shallow ground water increases the susceptibility to liquefaction (soil is more likely to liquefy). Soils that lack resistance (susceptible soils) typically are saturated, loose and sandy. Soils resistant to liquefaction include all soil types that are dry, cohesive, or sufficiently dense.

CGS's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps and historical occurrences, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil properties and soil conditions such as type, age, texture, color, and consistency, along with historical depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, liquefaction susceptibility maps typically are similar to Quaternary geologic maps. CGS's qualitative relations between geologic map unit and susceptibility are summarized in Table 1.2.

Geologic Map Unit	Sediment Type	Consistency	Age	Susceptible to Liquefaction?*
Qsc, Qsvc	fine to coarse sand, gravel	loose	latest Holocene	yes
Qds	fine to medium sand	loose	latest Holocene	yes
Q7c, Qvc	silty sand, fine to coarse sand, gravel	loose	latest Holocene	yes
Qal	silty sand, fine to coarse sand, gravel	Loose to medium dense	late Pleistocene to latest Holocene	yes
Q6m, Q6c	silty sand, fine to coarse sand, gravel	loose to medium dense	late Pleistocene and Holocene	yes
Ooa	silty sand, fine to coarse sand, gravel	dense to very dense	late Pleistocene and Holocene	not likely
Q4-5c	silty sand, fine to coarse sand, gravel	dense to very dense	late Pleistocene	not likely
Qbl, Qn	sand, pebble to boulder gravel	loose to weakly consolidated	Pleistocene	not likely
Q1-3c	sand, pebble to boulder gravel	weakly consolidated	Pleistocene	no

Table 1.2. Quaternary map units used in the Littlerock 7.5-Minute Quadrangle and their geotechnical characteristics and liquefaction susceptibility (*when saturated).

LIQUEFACTION OPPORTUNITY

Liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for strong ground shaking. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes is the level of peak ground acceleration (PGA) with a 10 percent probability of exceedance over a 50-year period (DOC, 2000). The earthquake magnitude used in CGS's analysis is the magnitude that contributes most to the calculated PGA for an area.

For the Littlerock Quadrangle, PGAs of 0.45 to 0.75g, resulting from an earthquake of magnitude 7.8, were used for liquefaction analyses. The PGA and magnitude values were based on de-aggregation of the probabilistic hazard at the 10 percent in 50-year hazard level (Petersen and others, 1996; Cramer and Petersen, 1996). See the ground motion portion (Section 3) of this report for further details.

Quantitative Liquefaction Analysis

CGS performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed-Idriss Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; National Research Council, 1985; Seed and others, 1985; Seed and Harder, 1990; Youd and Idriss, 1997; Youd and others, 2001). Using the Seed-Idriss Simplified Procedure one can calculate soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR), based on SPT results, ground-water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses expressed in terms of cyclic stress ratio (CSR). The Seed-Idriss Simplified Procedure requires normalizing earthquake loading relative to a M7.5 event for the liquefaction analysis. To accomplish this, CGS's analysis uses the Idriss magnitude-scaling factor (MSF) (Youd and Idriss, 1997). It is convenient to think in terms of a factor of safety (FS) relative to liquefaction, where: FS = (CRR / CSR) * MSF. FS, therefore, is a quantitative measure of liquefaction potential. CGS uses a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, to indicate the presence of potentially liquefiable soil. While an FS of 1.0 is considered the "trigger" for liquefaction, for a site specific analysis an FS of as much as 1.5 may be appropriate depending on the vulnerability of the site and related structures.

The CGS liquefaction analysis program calculates an FS for each geotechnical sample where blow counts were collected. Typically, multiple samples are collected for each borehole. The program then independently calculates an FS for each non-clay layer that includes at least one penetration test using the minimum $(N_1)_{60}$ value for that layer. The minimum FS value of the layers penetrated by the borehole is used to determine the liquefaction potential for each borehole location. The reliability of FS values varies according to the quality of the geotechnical data. FS, as well as other considerations such as slope, presence of free faces, and thickness and depth of potentially liquefiable soil, are evaluated in order to construct liquefaction potential maps, which are then used to make a map showing zones of required investigation.

Of the 70 geotechnical borehole logs reviewed in this study (Plate 1.2), 56 include blow-count data from SPTs or from penetration tests that allow reasonable blow count translations to SPT-equivalent values. Non-SPT values, such as those resulting from the use of 2-inch or 2½-inch inside-diameter ring samplers, were translated to SPT-equivalent values if reasonable factors could be used in conversion calculations. The reliability of the SPT-equivalent values varies. Therefore, they are weighted and used in a more qualitative manner. Few borehole logs, however, include all of the information (e.g. soil density, moisture content, sieve analysis, etc.) required for an ideal Seed-Idriss Simplified Procedure. For boreholes having acceptable penetration tests, liquefaction analysis is performed using recorded density, moisture, and sieve test values or using averaged test values of similar materials.

The Seed-Idriss Simplified Procedure for liquefaction evaluation was developed primarily for clean sand and silty sand. As described above, results depend greatly on accurate evaluation of in-situ soil density as measured by the number of soil penetration blow counts using an SPT sampler. However, many of the Holocene alluvial deposits in the study area contain a significant amount of gravel. In the past, gravelly soils were considered not to be susceptible to liquefaction because the high permeability of these soils presumably would allow the dissipation of pore pressures before liquefaction could occur. However, liquefaction in gravelly soils has been observed during earthquakes, and recent laboratory studies have shown that gravelly soils are susceptible to liquefaction (Ishihara, 1985; Harder and Seed, 1986; Budiman and Mohammadi, 1995; Evans and Zhou, 1995; and Sy and others, 1995). SPT-derived density measurements in gravelly soils are unreliable and generally too high. They are likely to lead to overestimation of the density of the soil and, therefore, result in an underestimation of the liquefaction susceptibility. To identify potentially liquefiable units where the N values appear to have been affected by gravel content, correlations were made with boreholes in the same unit where the N values do not appear to have been affected by gravel content.

LIQUEFACTION ZONES

Criteria for Zoning

Areas underlain by materials susceptible to liquefaction during an earthquake were included in liquefaction zones using criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the SMGB (DOC, 2000). Under those guideline criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historical earthquakes

2. All areas of uncompacted artificial fill containing liquefaction-susceptible material that are saturated, nearly saturated, or may be expected to become saturated

3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable

4. Areas where existing geotechnical data are insufficient

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historical high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (11,000 to 15,000 years), where the M7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historical high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria to liquefaction zoning in the Littlerock Quadrangle is summarized below.

Areas of Past Liquefaction

In the Littlerock Quadrangle, no areas of documented historical liquefaction are known. Areas showing evidence of paleoseismic liquefaction have not been reported.

Artificial Fills

In the Littlerock Quadrangle, artificial fill areas large enough to show at the scale of mapping consist of engineered fill for California Aqueduct. Since these fills are considered to be properly engineered, zoning for liquefaction in such areas depends on soil conditions in underlying strata. Non-engineered fills are commonly loose and uncompacted, and the material varies in size and type. In the Littlerock Quadrangle, there were no areas of non-engineered fill large enough to show at the scale of mapping.

Areas with Sufficient Existing Geotechnical Data

Borehole logs that include penetration test data and sufficiently detailed lithologic descriptions were used to evaluate liquefaction potential. These areas with sufficient geotechnical data were evaluated for zoning based on the liquefaction potential determined by the Seed-Idriss Simplified Procedure. Borehole logs encountered sediments from the following map units: Q7c, Qal, Q6m, Q6c, and Q4-5c. Among these, Q7c, Qal, Q6m, Q6c contain sediment layers that may liquefy under expected earthquake loading. Where these materials occur within the historically high ground-water limits, they are included in the zone.

Areas with Insufficient Existing Geotechnical Data

There are areas associated with Little Rock Wash, Rock Creek, and Big Rock Wash that are lacking in sufficient geotechnical data but were included within the zone. Subsurface characteristics from similar deposits from adjacent quadrangles were taken into consideration. Where the materials associated with these deposits occur within the historically highest ground-water occurrence they are included within the zone. Portions of the zoned area include an area previously identified by Leighton and Associates (1990, plate 4) as potentially liquefiable.

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AIR PHOTOS

Digital Orthophoto Quarter Quadrangle Photos, dated 10-4-95, northwest and southwest quarter quadrangle areas, Littlerock Quadrangle. (DOQQ and information concerning them can be obtained at http://www-wmc.wr.usgs.gov/doq/)

SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the Littlerock 7.5-Minute Quadrangle, Los Angeles County, California

By
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PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps prepared by CGS in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp

Following the release of DMG Special Publication 117 (DOC, 1997), agencies in the Los Angeles metropolitan region sought more definitive guidance in the review of geotechnical investigations addressing landslide hazards. The agencies made their request through the Geotechnical Engineering Group of the Los Angeles Section of the American Society of Civil Engineers (ASCE). This group convened an implementation committee in 1998 under the auspices of the Southern California Earthquake Center (SCEC). The committee, which consisted of practicing geotechnical engineers and engineering geologists, released an overview of the practice of landslide analysis, evaluation, and mitigation techniques (SCEC, 2002). This text is also on the Internet at: http://www.scec.org/

This section of the evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the Littlerock 7.5-Minute Quadrangle. Section 1 (addressing liquefaction) and Section 3 (addressing earthquake shaking), complete the report, which is one of a series that summarizes the preparation of seismic hazard zone maps within the state (Smith, 1996). Additional information on seismic hazard zone mapping in California can be accessed on the California Geological Survey's Internet page: http://www.consrv.ca.gov/CGS/index.htm

BACKGROUND

Landslides triggered by earthquakes historically have been a significant cause of earthquake damage. In California, large earthquakes such as the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes triggered landslides that were responsible for destroying or damaging numerous structures, blocking major transportation corridors, and damaging life-line infrastructure. Areas that are most susceptible to earthquake-induced landslides are steep slopes in poorly cemented or highly fractured rocks, areas underlain by loose, weak soils, and areas on or adjacent to existing landslide deposits. These geologic and terrain conditions exist in many parts of California, including numerous hillside areas that have already been developed or are likely to be developed in the future. The opportunity for strong earthquake ground shaking is high in many parts of California because of the presence of numerous active faults. The combination of these factors constitutes a significant seismic hazard throughout much of California, including the hillside areas of the Littlerock Quadrangle.

METHODS SUMMARY

The mapping of earthquake-induced landslide hazard zones presented in this report is based on the best available terrain, geologic, geotechnical, and seismological data. If unavailable or significantly outdated, new forms of these data were compiled or generated specifically for this project. The following were collected or generated for this evaluation:

- Digital terrain data were used to provide an up-to-date representation of slope gradient and slope aspect in the study area

- Geologic mapping was used to provide an accurate representation of the spatial distribution of geologic materials in the study area. In addition, a map of existing landslides, whether triggered by earthquakes or not, was prepared

- Geotechnical laboratory test data were collected and statistically analyzed to quantitatively characterize the strength properties and dynamic slope stability of geologic materials in the study area

- Seismological data in the form of CGS probabilistic shaking maps and catalogs of strong-motion records were used to characterize future earthquake shaking within the mapped area

The data collected for this evaluation were processed into a series of GIS layers using commercially available software. A slope stability analysis was performed using the Newmark method of analysis (Newmark, 1965), resulting in a map of landslide hazard potential. The earthquake-induced landslide hazard zone was derived from the landslide hazard potential map according to criteria developed in a CGS pilot study (McCrink and Real, 1996; McCrink, 2001) and adopted by the State Mining and Geology Board (DOC, 2000).

SCOPE AND LIMITATIONS

The methodology used to make this map is based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient. These data are gathered from a variety of outside sources. Although the selection of data used in this evaluation was rigorous, the quality of the data is variable. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data gathered from outside sources.

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Due to limitations in methodology, it should be noted that these zone maps do not necessarily capture all potential earthquake-induced landslide hazards. Earthquake-induced ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. It should also be noted that no attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the Littlerock Quadrangle, for more information on the delineation of liquefaction zones.

The remainder of this report describes in more detail the mapping data and processes used to prepare the earthquake-induced landslide zone map for the Littlerock Quadrangle. The information is presented in two parts. Part I covers physiographic, geologic and engineering geologic conditions in the study area. Part II covers the preparation of landslide hazard potential and landslide zone maps.

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The Littlerock 7.5-Minute Quadrangle covers approximately 62 square miles in the Antelope Valley in northeastern Los Angeles County. The center of the area is 10 miles east of Palmdale and 40 miles northeast of the Los Angeles Civic Center. Typical high desert scrubland and grassland of low local relief characterize most of the area. The southern slopes of Alpine Butte are in the northeastern corner. Irregular, hilly terrain along the San Andreas Fault Zone occurs in the extreme southwestern corner. Broad active channels and the adjacent floodplain of Little Rock Wash extend along the western part of the quadrangle. A segment of Big Rock Wash is in the northeastern corner. The eastern limits of the City of Palmdale cross into the western part of the quadrangle and extend eastward to 120th Street East, north of Avenue Q. Several square miles in the northwestern corner of the area lie within the proposed Palmdale International Airport. Most of the desert community of Littlerock and much of the smaller community of Pearblossom are within the quadrangle. Except for Palmdale, all other land in the quadrangle is unincorporated Los Angeles County land. Wildlife sanctuaries (Big Rock Creek, Alpine Butte, and Jackrabbit Flats) occur within the quadrangle. A large aggregate-mining operation with many gravel pits is adjacent to Little Rock Wash. A segment of the California Aqueduct and the Pearblossom Pumping Plant are in the southern part of the area. The highest point, above 3,320 feet, in the quadrangle is on the southern boundary in the southwestern corner. The lowest point, below 2,540 feet, is in Little Rock Wash in the northwestern corner. Land uses include residential developments, small ranches, mining, and recreation. Access to the region is primarily via State Highway 138 (Pearblossom Highway) and a grid of east-west avenues (lettered) and north-south streets (numbered).

Digital Terrain Data

The calculation of slope gradient is an essential part of the evaluation of slope stability under earthquake conditions. An accurate slope gradient calculation begins with an up-to-date map representation of the earth's surface in the form of a digital topographic map. Within the Littlerock Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1993). This DEM, prepared from the 7.5-minute quadrangle topographic contours based on 1955 aerial photography, has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy.

Recent aggregate mining has created large gravel pits with steep slopes in the southwestern part of the quadrangle. The topography of these areas was updated to reflect the new conditions. A DEM reflecting this recent mining was obtained from an airborne interferometric radar platform flown in 2001, with an estimated vertical accuracy of approximately 1.5 meters (Intermap Corporation, 2002). An interferometric radar DEM is prone to creating false topography where tall buildings, metal structures or trees are present. The DEM used for the graded areas within the Littlerock Quadrangle underwent additional processing to remove these types of artifacts (Wang and others, 2001). Nevertheless, the final hazard zone map was checked for potential errors resulting from the use of the radar DEM and corrected if necessary. Graded areas associated with gravel pits where the radar DEM was applied are shown on Plate 2.1.

A slope map was made from both the USGS and radar DEMs using a third-order, finite difference, center-weighted algorithm (Horn, 1981). The manner in which the slope maps were used to prepare the zone map will be described in subsequent sections of this report.

GEOLOGY

Bedrock and Surficial Geology

Ponti and Burke (1980) mapped the Quaternary geology of eastern Antelope Valley and vicinity, including the Littlerock Quadrangle. Pre-Quaternary sedimentary and crystalline rocks are generalized on their map. Detailed geologic maps of the San Andreas Fault Zone, including the segment that traverses the southwestern corner of the Littlerock Quadrangle, were prepared by Barrows and others (1985, Plates 1F and 1G). Geologic maps from both of these sources were digitized by the Southern California Areal Mapping Project [SCAMP] for use as background geology. Landslide deposits are nearly non-existent in the quadrangle. During the search for landslides in the field observations were made of exposures, aspects of weathering, and general surface expression of the geologic units.

The only pre-Quaternary bedrock exposed in the quadrangle is in the hills in the southwestern corner. The oldest rock in the quadrangle is Holcomb Quartz Monzonite (hqm) (Barrows and others, 1985). Quartz monzonite crops out in hills north of the Little Rock Fault, which is parallel to and about 1,500 feet to the north of the San Andreas Fault. These crystalline basement rocks belong to a granitic batholith that extends across the western Mojave Desert (Dibblee, 1967).

Several members of the non-marine Miocene Anaverde Formation are exposed in the dissected terrain between the Little Rock Fault and the San Andreas Fault east of Little Rock Creek. These include the white arkose member (Taw), red arkose menber (Tar), and buff arkose member (Tab) (Barrows and others, 1985). The white arkose member (Taw) is a massive coarse-grained arkosic sandstone that resembles weathered granite. It grades upward into the red arkose member (Tar), within a zone of interlayered red and white beds. Tar is a pink to red medium to thick bedded, locally massive, coarse pebbly arkose. The buff arkose (Tab) is a buff to gray, medium-bedded to massive, medium- to very coarse-grained pebbly arkose with thin silty interbeds near the top. The bedding within these members mostly parallels the bounding faults and has steep to vertical dips.

Small exposures of crushed, white to pink, undifferentiated granitic rocks (gru) occur in the southwesternmost corner of the Littlerock Quadrangle south of the San Andreas Fault. Also within this corner are two highly deformed members of the non-marine Plio-

Pleistocene Juniper Hills Formation (Barrows, 1975; 1980; 1987). The arkosic basal breccia member (TQjhb) is a white to buff, coarse, poorly sorted arkosic sedimentary breccia and fanglomerate with boulder-size blocks of various granitic rocks. Also exposed in this corner is the mixed-clast member (TQjhm), which is a white to buff, and locally chaotic, pebbly arkosic sandstone and angular cobble to boulder conglomerate with a variety of clasts ranging in composition from volcanic to metamorphic.

Structural Geology

Most of the quadrangle is underlain by a granitic batholith that extends across the western Mojave Desert (Dibblee, 1967). Several traces of the Mojave Segment of the San Andreas Fault Zone traverse the very southwestern corner of the Littlerock Quadrangle (Barrows and others, 1985). This segment of the San Andreas Fault ruptured during the great 1857 Fort Tejon earthquake and is considered the predominant source of future earthquake shaking in this area (Petersen and others, 1996).

Landslide Inventory

As a part of the geologic data compilation, a search for landslides in the Littlerock Quadrangle was performed by field reconnaissance, analysis of stereo-paired aerial photographs and a review of previously published geologic mapping. No landslides were found in the Littlerock Quadrangle other than temporary ones associated with the steep slopes of piled aggregate in the gravel mines. However, the aprons of coarse colluvial talus and slope wash indicate that rock falls may be the predominant form of slope failure around the buttes and hillsides.

ENGINEERING GEOLOGY

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, the geologic map units described above were ranked and grouped on the basis of their shear strength. Generally, the primary source for shear-strength measurements is geotechnical reports prepared by consultants on file with local government permitting departments. Only 20 shear tests were found for the Littlerock Quadrangle, all for alluvium (see Plate 2.1). Shear tests used to characterize other geologic units in the Littlerock Quadrangle were borrowed from the nearby Ritter Ridge, Juniper Hills, Palmdale, Val Verde and Hi Vista quadrangles. Average (mean or median) phi values for each strength group are summarized in Table 2.1. For the geologic strength groups (Table 2.2) in the map area, a single shear strength value was assigned and used in our slope stability analysis. A geologic material strength map was made based on the groupings presented in Table 2.1 and Table 2.2, and this map provides a spatial representation of material strength for use in the slope stability analysis.

LITTLEROCK QUADRANGLE SHEAR STRENGTH GROUPS							
	Formation Name	**Number Tests**	**Mean/Median Phi (deg)**	**Mean/Median Group Phi (deg)**	**Mean/Median Group C (psf)**	**No Data: Similar Lithology**	**Phi Values Used in Stability Analyses**
GROUP 1	**gr**	**41**	**34/35**	**34/35**	**376/326**	**gr-m**	**34**
	qd	**2**	**32**			**gr-pediment**	
	hqm	**11**	**36**			**gru**	
GROUP 2	**Qa**	**51**	**30**	**30/31**	**215/170**	**af**	**30**
	Qoa	**14**	**29/31**			**All Q**	
	Tas	**14**	**30/31**			**Tab, Tar, Taw**	
						TQjhb, TQjhm	
GROUP 3	**Tac**	**9**	**24/26**	**26**	**477/280**		**26**

Formation abbreviations from Barrows and others, 1985

Table 2.1. Summary of the Shear Strength Statistics for the Littlerock Quadrangle.

SHEAR STRENGTH GROUPS FOR THE LITTLEROCK 7.5-MINUTE QUADRANGLE		
GROUP 1	**GROUP 2**	**GROUP 3**
gr	af	Tac
Gr-m	All Q	
gr-pediment	Tab	
gru	Tar	
hqm	Tas	
qd	Taw	
	TQjhb	
	TQjhm	

Table 2.2. Summary of Shear Strength Groups for the Littlerock Quadrangle.

PART II

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Design Strong-Motion Record

To evaluate earthquake-induced landslide hazard potential in the study area, a method of dynamic slope stability analysis developed by Newmark (1965) was used. The Newmark method analyzes dynamic slope stability by calculating the cumulative down-slope displacement for a given earthquake strong-motion time history. As implemented for the preparation of earthquake-induced landslide zones, the Newmark method necessitates the selection of a design earthquake strong-motion record to provide the "ground shaking opportunity". For the Littlerock Quadrangle, selection of a strong motion record was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by DMG for a 10 percent probability of being exceeded in 50 years (Petersen and others, 1996). The parameters used in the record selection are:

Modal Magnitude:	7.8
Modal Distance:	2.8 to 15.8 km
PGA:	0.44g to 0.89g

The strong-motion record selected for the slope stability analysis in the Littlerock Quadrangle was the Southern California Edison (SCE) Lucerne record from the 1992 magnitude 7.3 Landers, California, earthquake. This record had a source to recording site distance of 1.1 km and a peak ground acceleration (PGA) of 0.80g. Although the magnitude and PGA values of the Lucerne record do not fall within the range of the probabilistic parameters, this record was considered to be sufficiently conservative to be used in the stability analyses. The selected strong-motion record was not scaled or otherwise modified prior to its use in the analysis.

Displacement Calculation

The design strong-motion record was used to develop a relationship between landslide displacement and yield acceleration (a_y), defined as the earthquake horizontal ground acceleration above which landslide displacements take place. This relationship was prepared by integrating the design strong-motion record twice for a given acceleration value to find the corresponding displacement, and the process was repeated for a range of acceleration values (Jibson, 1993). The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for the design strong-motion record. This curve provides the required link between anticipated earthquake shaking and estimates of displacement for different combinations of geologic materials and slope gradient, as described in the Slope Stability Analysis section below.

The amount of displacement predicted by the Newmark analysis provides an indication of the relative amount of damage that could be caused by earthquake-induced landsliding. Displacements of 30, 15 and 5 cm are used as criteria for rating levels of earthquake-induced landslide hazard potential based on the work of Youd (1980), Wilson and Keefer (1983), and the CGS pilot study for earthquake-induced landslides (McCrink and Real, 1996; McCrink, 2001). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.148, 0.182, and 0.243 g. Because these yield acceleration values are derived from the design strong-motion record, they represent the ground shaking opportunity thresholds that are significant to the Littlerock Quadrangle.

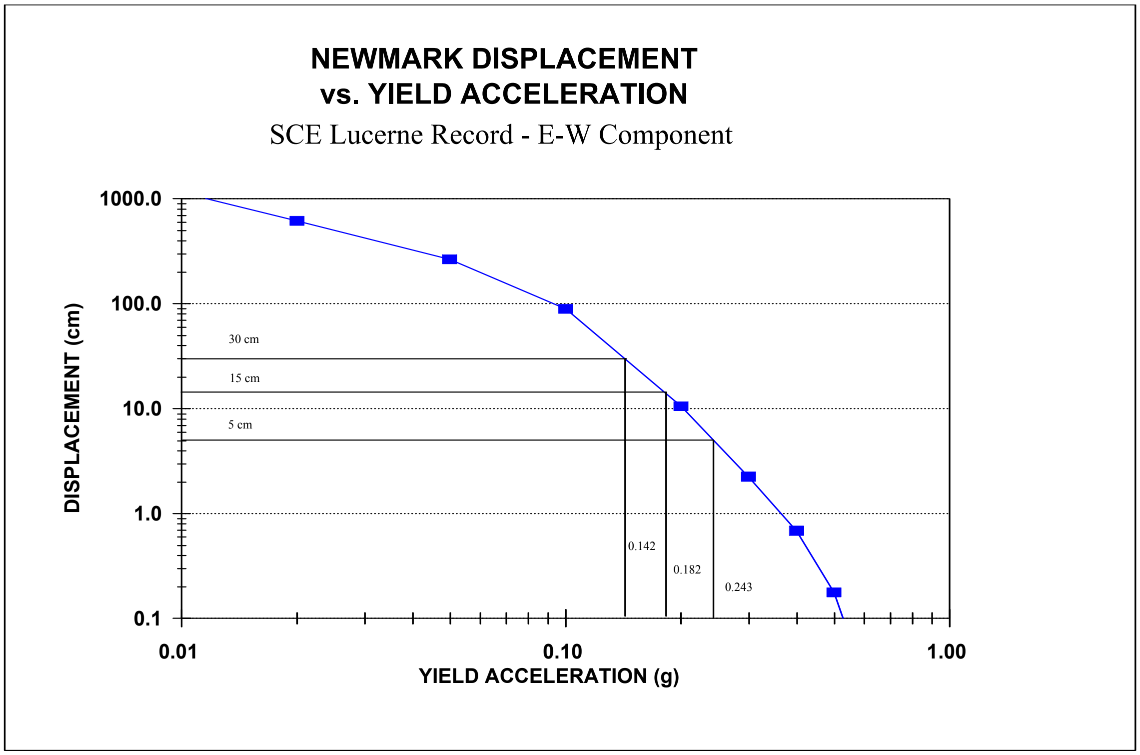

Figure 2.1. Yield Acceleration vs. Newmark Displacement for the 1992 Landers Earthquake SCE Lucerne Record.

Slope Stability Analysis

A slope stability analysis was performed for each geologic material strength group at slope increments of 1 degree. An infinite-slope failure model under unsaturated slope conditions was assumed. A factor of safety was calculated first, followed by calculation of yield acceleration from Newmark's equation:

$$a_y = (FS - 1)g \sin \alpha$$

where FS is the Factor of Safety, g is the acceleration due to gravity, and α is the direction of movement of the slide mass, in degrees measured from the horizontal, when displacement is initiated (Newmark, 1965). For an infinite slope failure, α is the same as the slope angle.

The yield accelerations resulting from Newmark's equations represent the susceptibility to earthquake-induced failure of each geologic material strength group for a range of slope gradients. Based on the relationship between yield acceleration and Newmark displacement shown in Figure 2.1, hazard potentials were assigned as follows:

1. If the calculated yield acceleration was less than 0.14g, Newmark displacement greater than 30 cm is indicated, and a HIGH hazard potential was assigned.

2. Likewise, if the calculated yield acceleration fell between 0.14g and 018.g, Newmark displacement between 15 cm and 30 cm is indicated, and a MODERATE hazard potential was assigned.

3. If the calculated yield acceleration fell between 0.18g and 0.24g, Newmark displacement between 5 cm and 15 cm is indicated, and a LOW hazard potential was assigned.

4. If the calculated yield acceleration was greater than 0.24g, Newmark displacement of less than 5 cm is indicated, and a VERY LOW potential was assigned.

Table 2.3 summarizes the results of the stability analyses. The earthquake-induced landslide hazard potential map was prepared by combining the geologic material-strength map and the slope map according to this table.

LITTLEROCK QUADRANGLE HAZARD POTENTIAL MATRIX				
Geologic Material Strength Group (Average Phi)	HAZARD POTENTIAL (Percent Slope)			
	Very Low	Low	Moderate	High
1 (34)	0 to 42%	42 to 48%	48 to 53%	>53%
2 (30)	0 to 32%	32 to 38%	38 to 42%	>42%
3 (26)	0 to 25%	25 to 30%	30 to 34%	>34%

Table 2.3. Hazard Potential Matrix for Earthquake-Induced Landslides in the Littlerock Quadrangle. Values in the table show the range of slope gradient (expressed as percent slope) corresponding to calculated Newmark displacement ranges from the design earthquake for each material strength group.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (DOC, 2000). Under these criteria, earthquake-induced landslide hazard zones are defined as areas that meet one or both of the following conditions:

1. Areas that have been identified as having experienced landslide movement in the past, including all mappable landslide deposits and source areas as well as any landslide that is known to have been triggered by historic earthquake activity.

2. Areas where the geologic and geotechnical data and analyses indicate that the earth materials may be susceptible to earthquake-induced slope failure.

These conditions are discussed in further detail in the following sections.

Existing Landslides

As previously mentioned, no landslides were mapped in the Littlerock Quadrangle. However, the presence of colluvial aprons around the steep sides of the buttes indicates that rock fall, possibly triggered by earthquake shaking, is an ongoing geologic process around the buttes. The areas most susceptible to rock fall were identified in the geologic and geotechnical analyses, described below.

Geologic and Geotechnical Analysis

Based on the conclusions of a pilot study performed by CGS (McCrink and Real, 1996; McCrink, 2001), it has been concluded that earthquake-induced landslide hazard zones should encompass all areas that have a High, Moderate or Low level of hazard potential (see Table 2.3). This would include all areas where the analyses indicate earthquake displacements of 5 centimeters or greater. Areas with a Very Low hazard potential, indicating less than 5 centimeters displacement, are excluded from the zone.

As summarized in Table 2.3, all areas characterized by the following geologic strength group and slope gradient conditions are included in the earthquake-induced landslide hazard zone:

1. Geologic Strength Group 3 is included for all slopes steeper than 25 percent.
2. Geologic Strength Group 2 is included for all slopes steeper than 32 percent.
3. Geologic Strength Group 1 is included for all slopes steeper than 42 percent.

This results in less than one percent of the quadrangle lying within the earthquake-induced landslide hazard zone for the Littlerock Quadrangle.

ACKNOWLEDGMENTS

The authors would like to thank the following individuals and organizations for their assistance in obtaining the data necessary to complete this project. Charles Nestle and Robert Larson from the Los Angeles County Materials Engineering Division, Dan Schneidereit and Bruce Hick of Earth Systems and Michael Mischel of the City of Palmdale provided assistance and access for collection of geologic material strength data, and review of geotechnical reports. Terilee McGuire and Bob Moscovitz provided GIS support. Ante Perez and Barbara Wanish merged the digital files for the composite geologic map. Barbara Wanish and Diane Vaughan prepared the final landslide hazard zone maps and the graphic displays for this report.

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APPENDIX A
SOURCE OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
Los Angeles County	**20**
Ritter Ridge Quadrangle	**65**
Juniper Hills Quadrangle	**32**
Palmdale Quadrangle	**17**
Val Verde Quadrangle	**5**
Hi Vista Quadrangle	**3**
Total Number of Shear Tests	**142**

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the Littlerock 7.5-Minute Quadrangle, Los Angeles County, California

By

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California Geological Survey
***Formerly with CGS, now with U.S. Geological Survey**

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5-minute quadrangle and portions of the adjacent eight quadrangles. They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the “Simple Prescribed Parameter Value” method (SPPV) described in the site investigation guidelines (DOC, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections 1 and 2 (addressing liquefaction and earthquake-induced landslide hazards) constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on the California Geological Survey's Internet page: http://www.consrv.ca.gov/CGS/index.htm

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology [California Geological Survey], and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10 percent probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

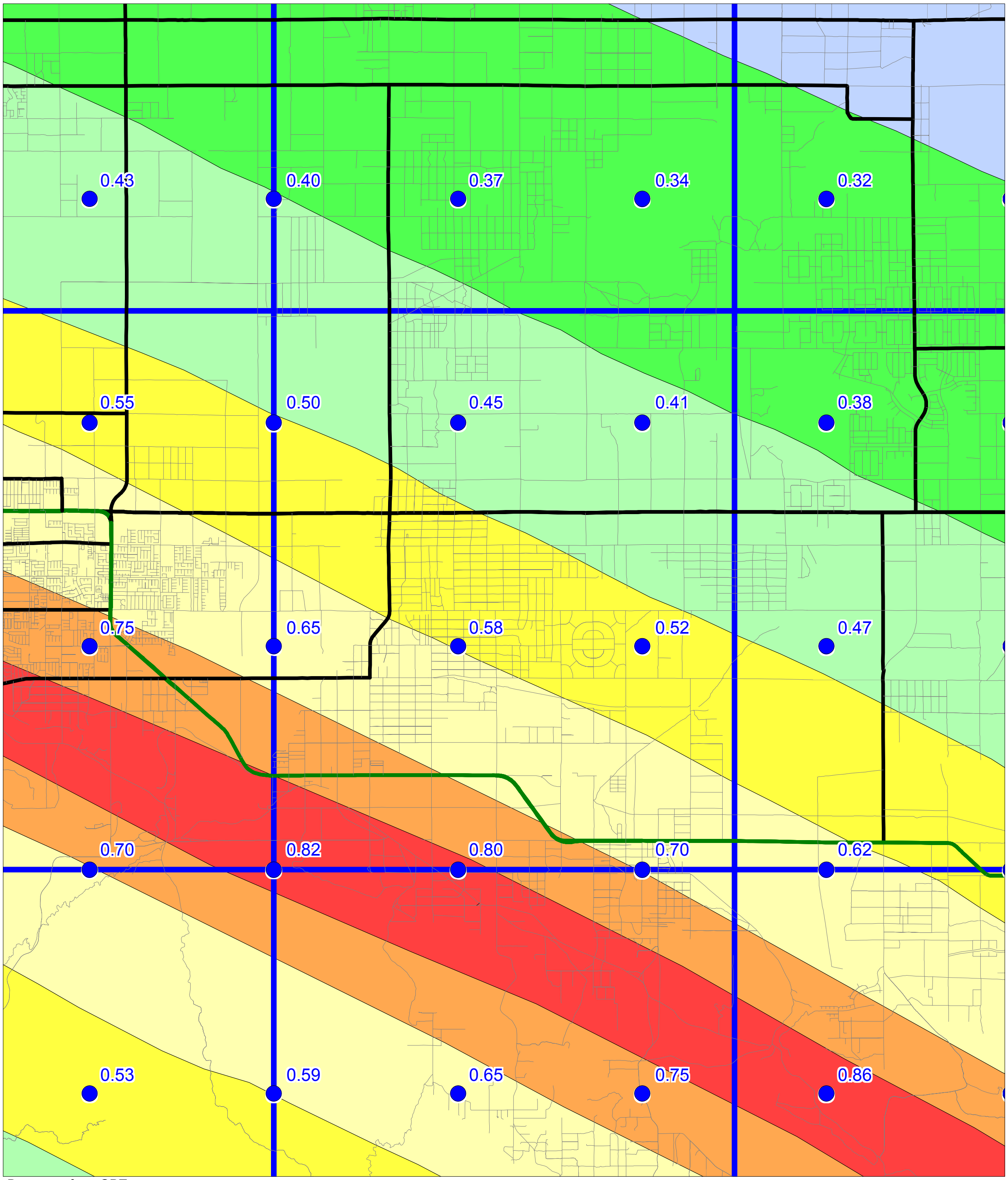
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10 percent probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight

LITTLEROCK 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

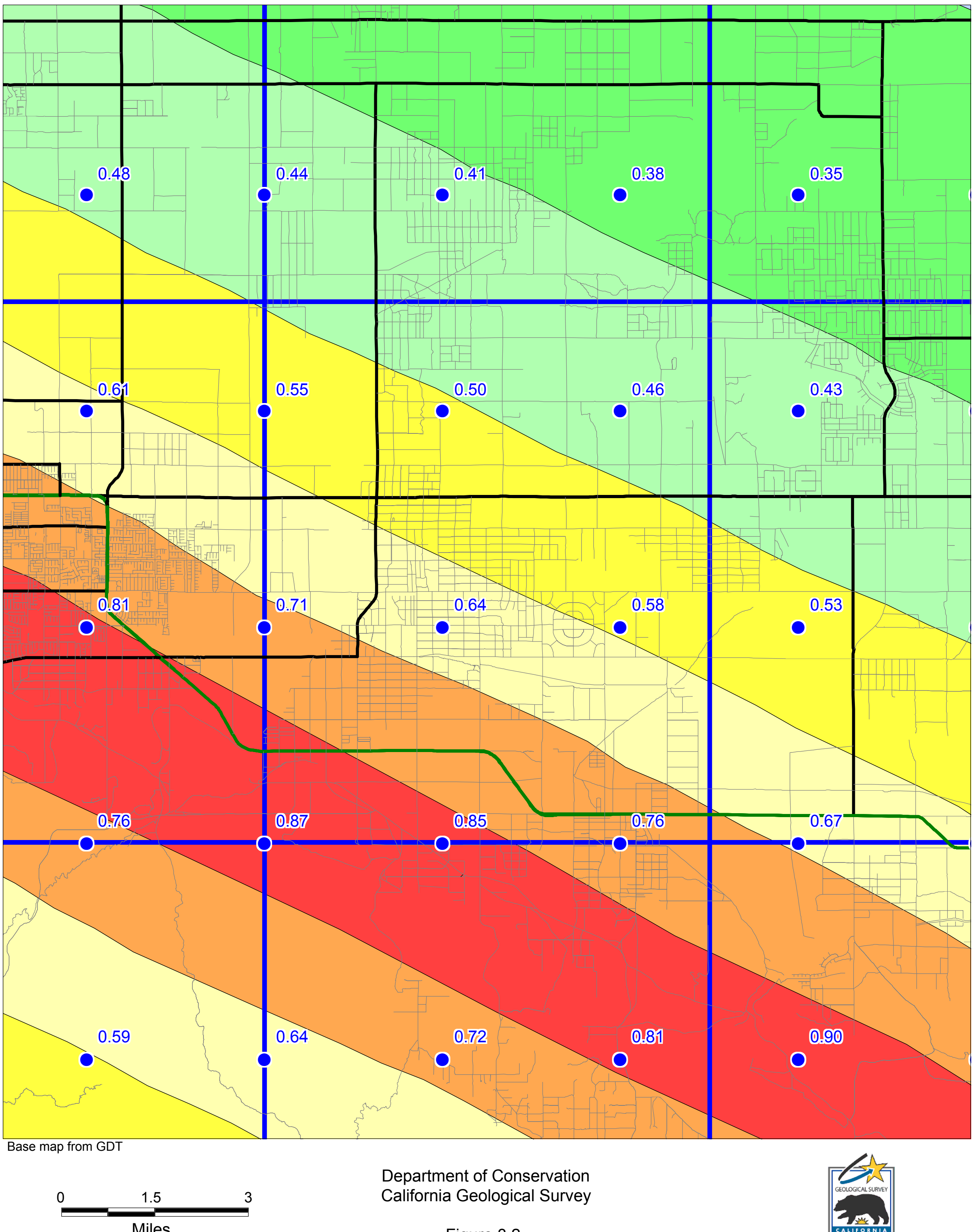
Figure 3.1

LITTLEROCK 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



Department of Conservation
California Geological Survey

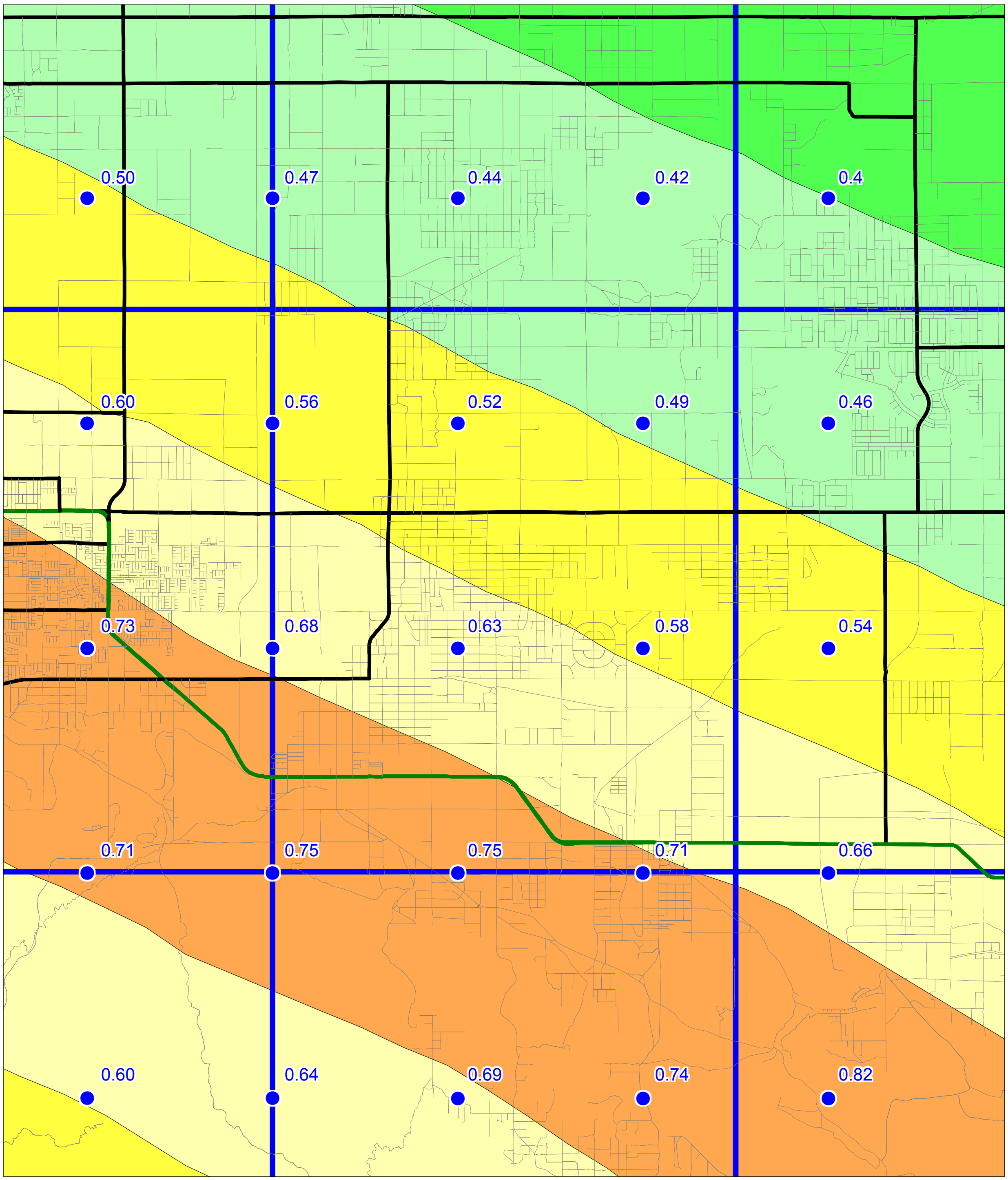
Figure 3.2

LITTLEROCK 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

ALLUVIUM CONDITIONS



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

Figure 3.3

adjacent quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10 percent probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

A preferred method of using the probabilistic seismic hazard model and the "simplified Seed-Idriss method" of assessing liquefaction hazard is to apply magnitude scaling probabilistically while calculating peak ground acceleration for alluvium. The result is a "magnitude-weighted" ground motion (liquefaction opportunity) map that can be used directly in the calculation of the cyclic stress ratio threshold for liquefaction and for estimating the factor of safety against liquefaction (Youd and Idriss, 1997). This can provide a better estimate of liquefaction hazard than use of predominate magnitude described above, because all magnitudes contributing to the estimate are used to weight the probabilistic calculation of peak ground acceleration (Real and others, 2000). Thus, large distant earthquakes that occur less frequently but contribute *more* to the liquefaction hazard are appropriately accounted for.

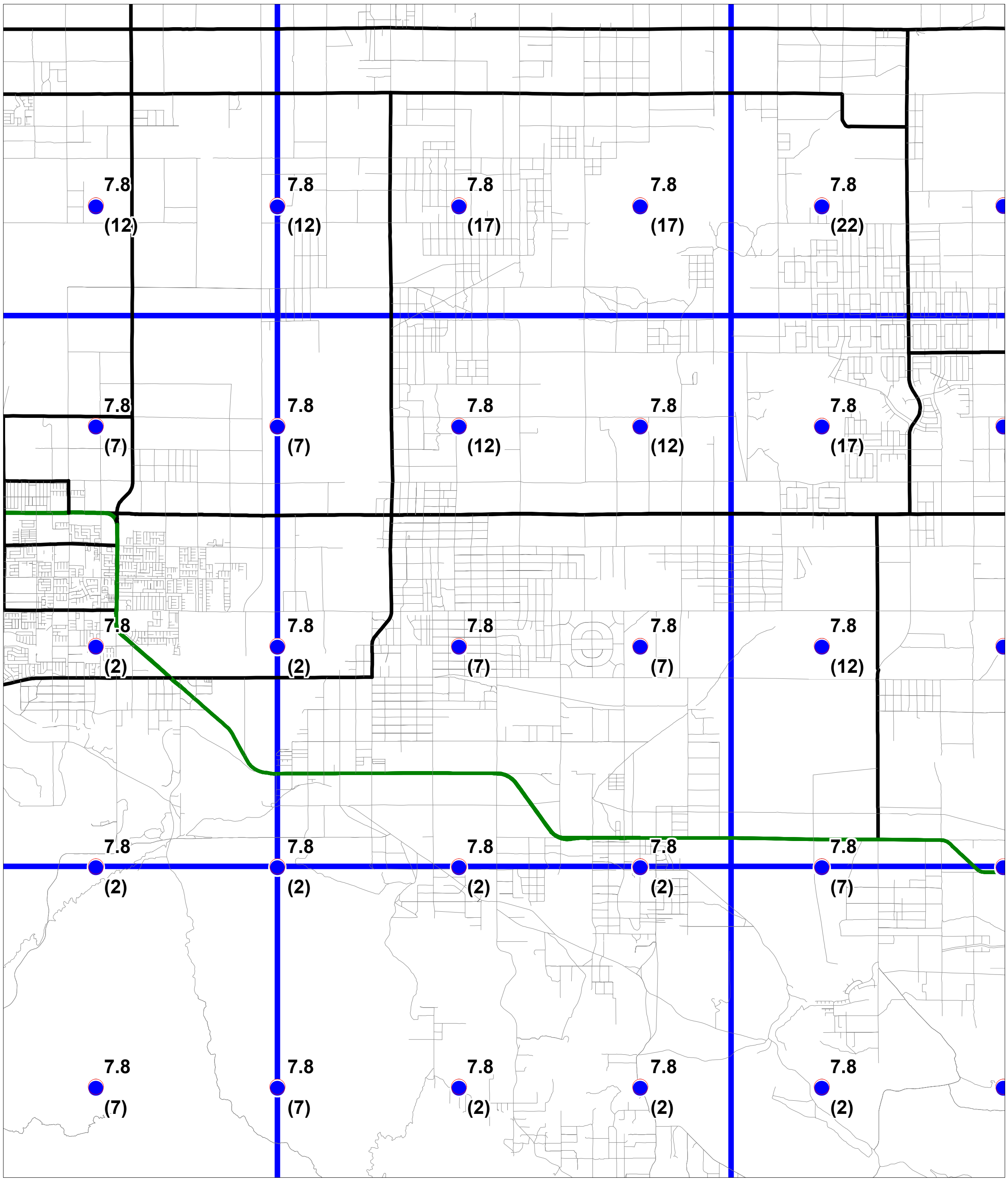
Figure 3.5 shows the magnitude-weighted alluvial PGA based on Idriss' weighting function (Youd and Idriss, 1997). It is important to note that the values obtained from this map are pseudo-accelerations and should be used in the formula for factor of safety without any magnitude-scaling (a factor of 1) applied.

LITTLEROCK 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE
Magnitude (Mw)
(Distance (km))



Base map from GDT

0 1.5 3
Miles

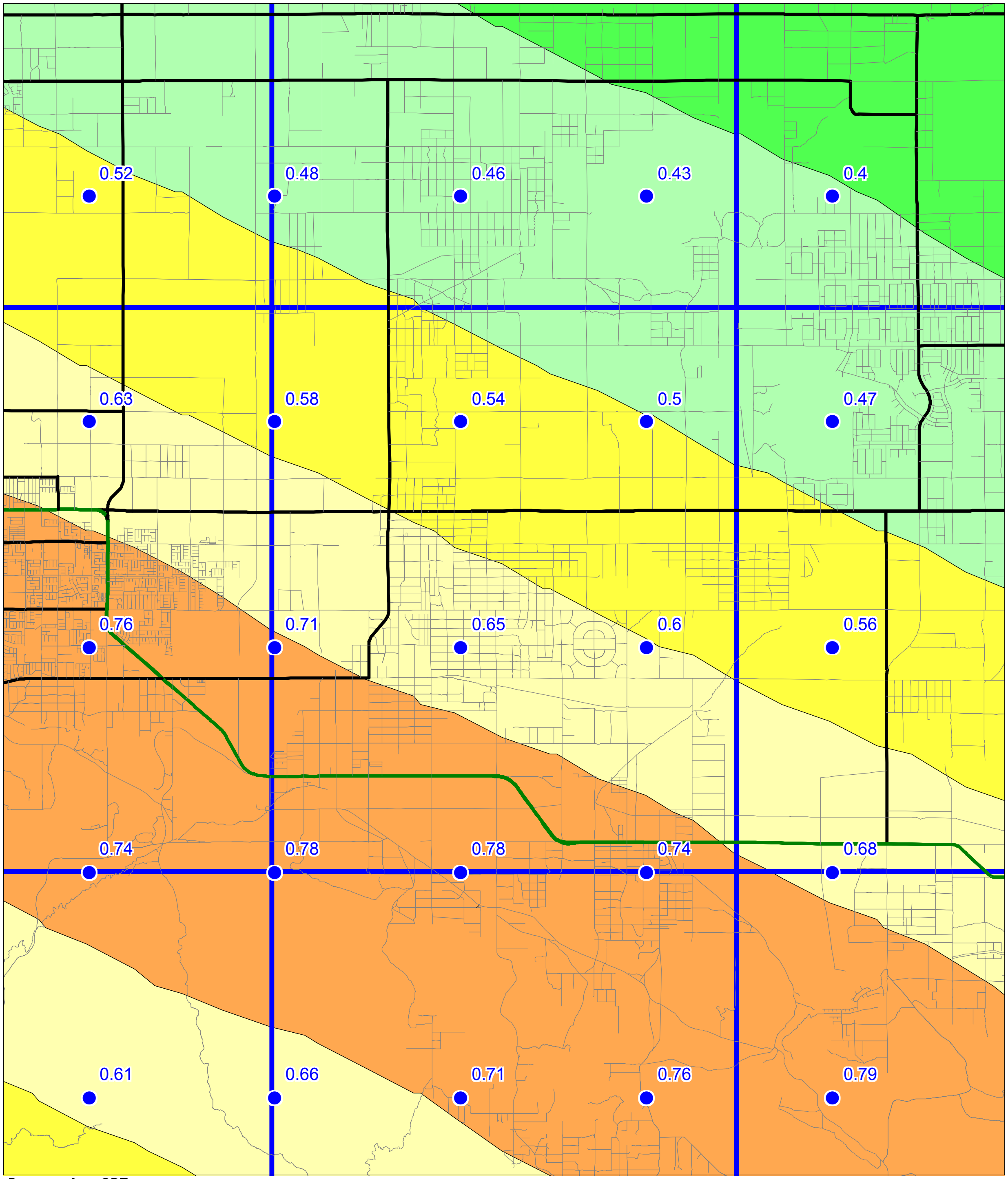
Department of Conservation
California Geological Survey
Figure 3.4

LITTLEROCK 7.5 MINUTE QUADRANGLE AND PORTIONS OF
ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS MAGNITUDE-WEIGHTED PSEUDO-PEAK ACCELERATION (g)
FOR ALLUVIUM

1998

LIQUEFACTION OPPORTUNITY



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

Figure 3.5

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.

2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours*.

3. Uncertainties in the hazard values have been estimated to be about +/- 50 percent of the ground motion value at two standard deviations (Cramer and others, 1996).

4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not been previously recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.

5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (DOC, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the "importance" or sensitivity of the proposed building with regard to occupant safety.

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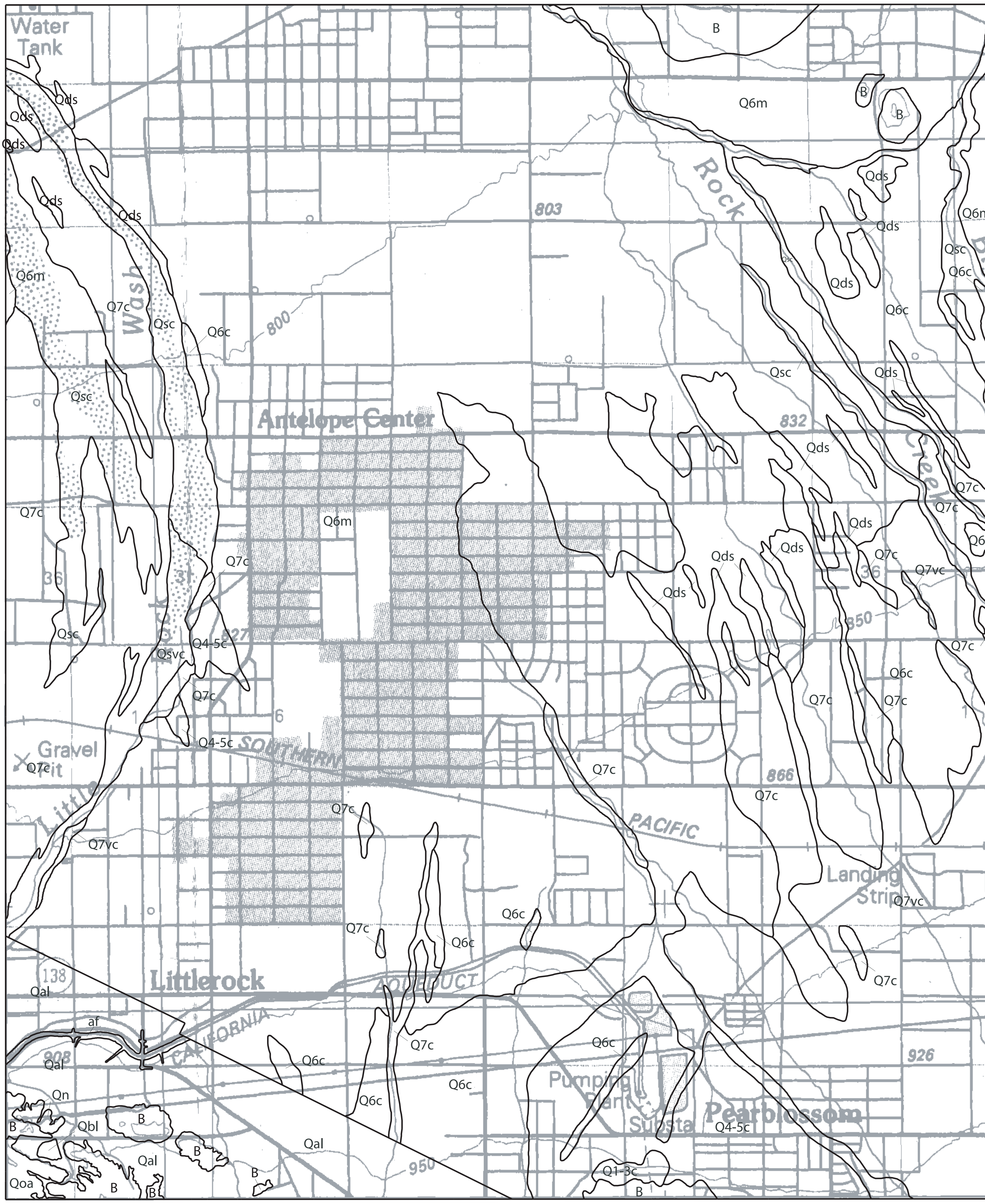


Base map enlarged from U.S.G.S. 30 x 60-minute series

LITTLEROCK QUADRANGLE

SCALE

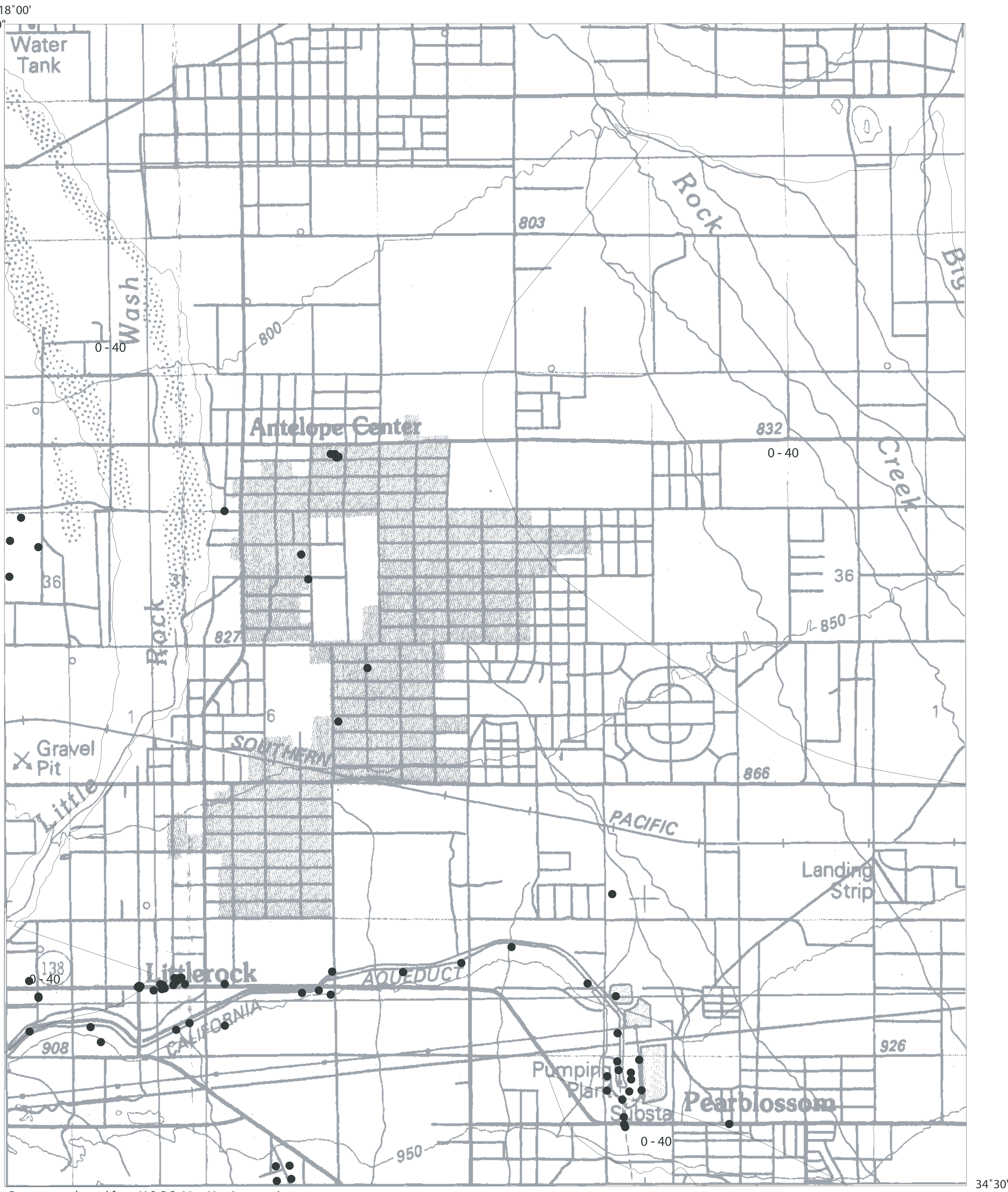
1 .5 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER

N

See "Bedrock and Surficial Geology" in Section 1 of report for descriptions of units.

B = Pre-Quaternary bedrock.

Plate 1.1 Quaternary Geologic Map of the Littlerock 7.5-Minute Quadrangle, California



Base map enlarged from U.S.G.S. 30 x 60-minute series

LITTLEROCK QUADRANGLE

SCALE

1 .5 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER

N

0 - 40 Depth to ground water, in feet

● Geotechnical borings used in liquefaction evaluation

Plate 1.2 Depth to historically high ground water and locations of boreholes used in this study, Littlerock 7.5-minute Quadrangle, California